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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXXXVII.

(Vol. VIII.—October, 1879.)

THE CONSTRUCTION OF THE ATCHISON, TOPEKA AND SANTA FÉ RAILROAD OVER THE RATON MOUNTAINS, AND THE PERFORMANCE OF LOCOMOTIVES ON ITS STEEP GRADES.

By JAMES D. BURR, C. E., Member of the Society.

PRESENTED AT THE ELEVENTH ANNUAL CONVENTION, JUNE 17TH, 1879.

The railroad over the Raton Mountains, of standard 4′ 8½″ gauge, is a branch of the Atchison, Topeka and Santa Fé Railroad, under the names of Pueblo and Arkansas Valley, in Colorado; and New Mexico and Southern Pacific, in the Territory of New Mexico.

The Raton Mountains, a spur of the Sangre de Christo, or Snowy Range, extend nearly due east and west; while the Snowy Range, a portion of the Rocky Mountain system, extends almost due north and south, parallel to the direction of the road. The Ratons culminate in Raton (or Fisher's) Peak, 9 800 feet above the level of the sea, while the summit of Raton Pass is reached by the grade line at an elevation of 7 720 feet above the same plane.

A cross-section of the country from La Junta, Col., in the Arkansas Valley, to Las Vegas, New Mexico, over the line of the constructed road, is shown on Plate L. A map and profile of the Mountain Division, Trinidad to Willow Springs, is shown on Plate LI.

Plate LII, is a map and profile of the temporary track, or "Switchback."

Table 1 gives the distances, grades and curvatures from La Junta to Las Vegas.

Table 2 gives a statement of the progress of Raton Tunnel, kindly furnished by R. L. Engle, C. E., Engineer in charge of the construction of the Mountain Division, including Tunnel and "Switchback."

Plate LIII shows the Consolidation Engine, "Uncle Dick."

La Junta, Colorado, 555 miles west of Atchison, Kansas, at an elevation of 4041 feet above tidewater, is the point where the Trinidad Branch of the Pueblo and Arkansas Valley Railroad diverges from the main line. This Branch extends to the boundary line of the Territory of New Mexico (97 miles from La Junta), at which point the New Mexico and Southern Pacific Railroad begins. This latter road is now nearly completed as far as Las Vegas, N. M., a distance of 118 miles from the boundary line.

From La Junta, Col., to Trinidad, a distance of 81 miles, maximum ascending grades of 60 feet per mile have been used, with adverse grades of 30 feet per mile. Curves of 1146 feet radius are used, with a compensation or reduction of grades on curves at the rate of .05 foot each 100 feet, for each degree of curvature.

To preserve uniformity throughout, the following rules were adopted :

1st. Generally, the point from which to commence elevating the outer rail on curves, shall be on the tangent, 150 feet from point of curve, and shall attain its proper elevation at the point of curve.

2d. In cases of compound curves, or curves in the same direction where there is less than 300 feet tangent between curves, the same rule will apply,

3d. In cases of curves in reverse direction with only 100 feet tangent between them, the elevation shall begin at the point of tangent to the curve on the inner rail and attain its proper elevation at the point of curve on the outer rail, of the succeeding curve, and so, in an opposite sense, for the other rail.

There are thus on curves of this class, two planes inclined in opposite directions relative to the true grade line.

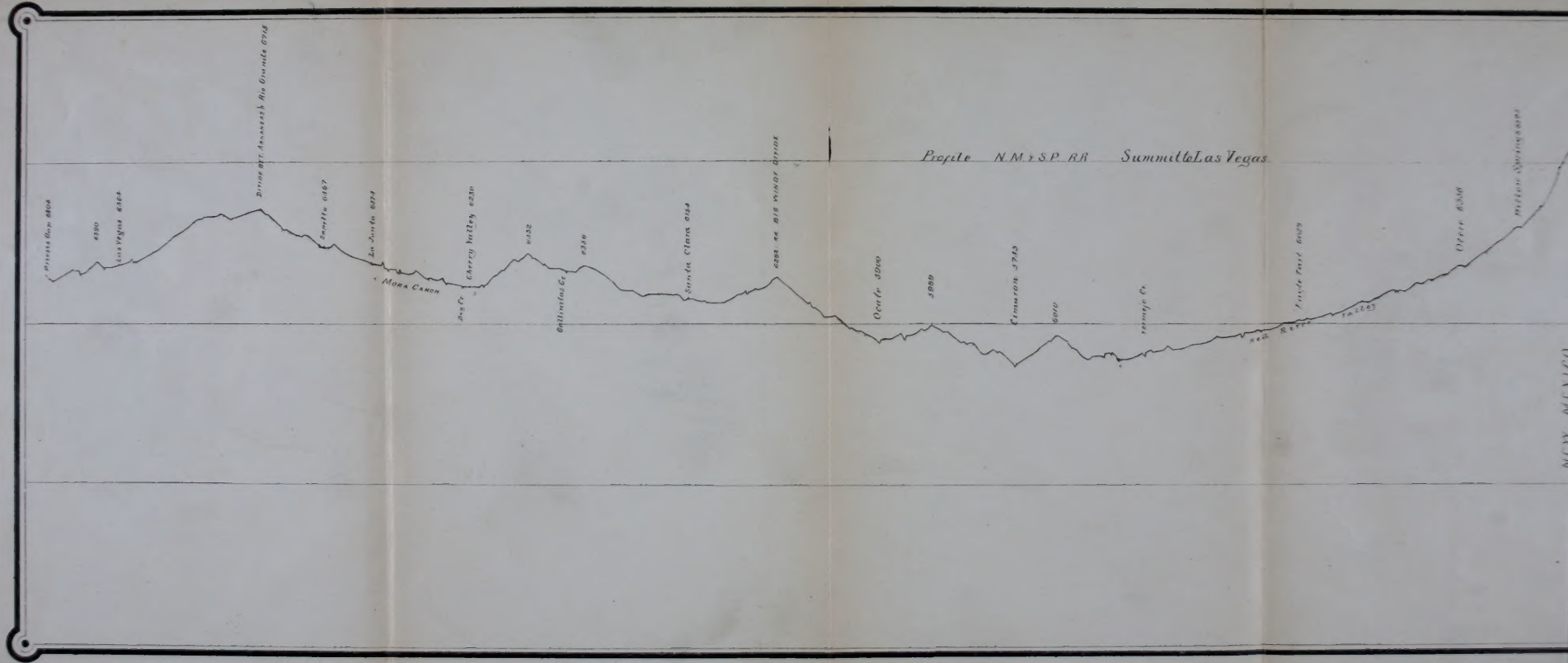
Profile N.M. & S.P. RR Summit to Las Vegas
Las Vegas 6565
Summit 6787
La Junta 6754
Mora Canon
Dry Cr.
Cherry Valley 6330
6532
Gallinitas Cr.
6350
Simeon Clark 6154
6282 at Big Windy Arroyo
Ocate 5900
5989
Cimarron 5743
6010
Turkey Cr.
Rock Rest
Trinchera Creek 6609
Raton 6588
Raton Summit 6832

PLATE I.
TRANS. AM. SOC. CIV. ENGRS.
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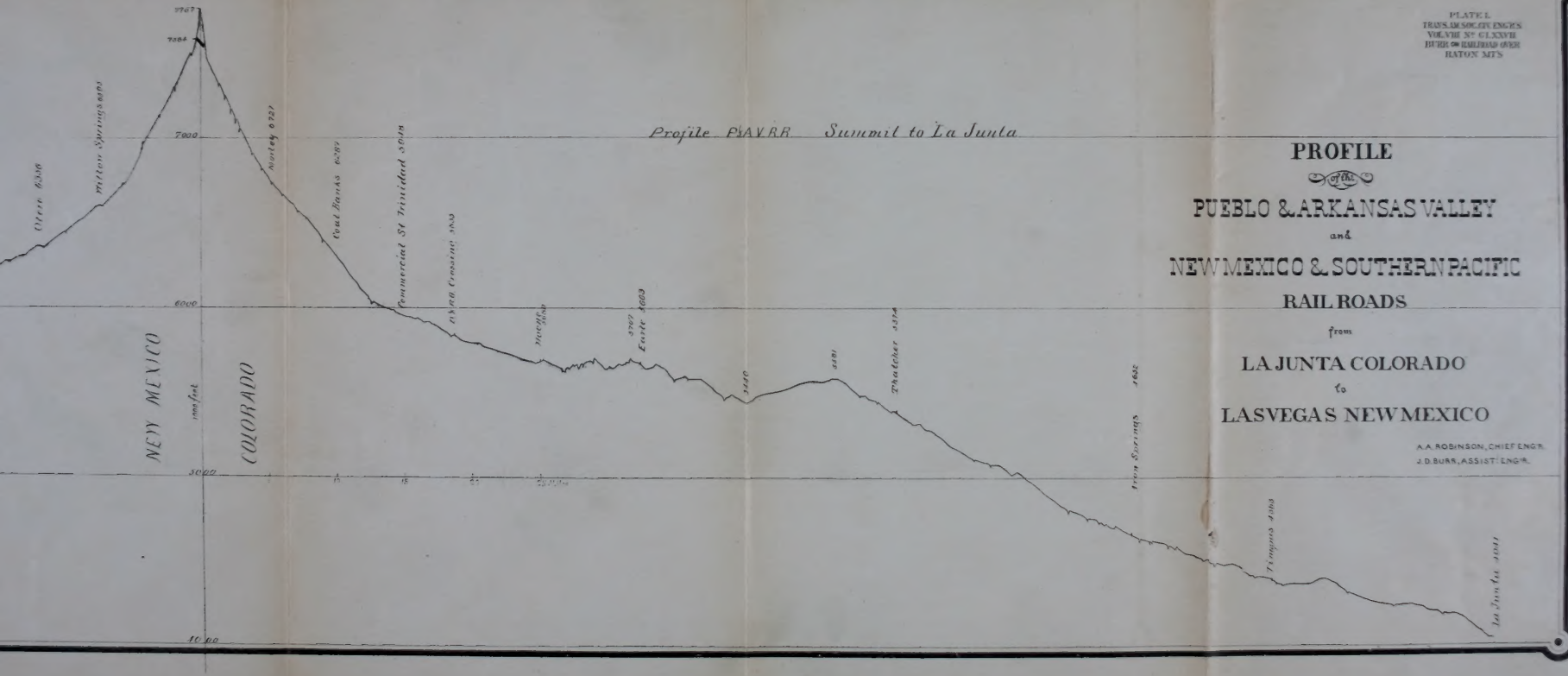
BURR ON RAILROAD OVER RATON MTS



PROFILE
of the
PUEBLO & ARKANSAS VALLEY
and
NEW MEXICO & SOUTHERN PACIFIC
RAIL ROADS
from
LA JUNTA COLORADO
to
LAS VEGAS NEW MEXICO

A.A. ROBINSON, CHIEF ENG'R.
J.D. BURR, ASSIST. ENG'R.

TABLE 1.

DISTANCES, GRADES AND CURVATURE FROM LA JUNTA, COL., TO LAS VEGAS, N. M.

	Distance in miles.	Total Rise.	Total Fall.	Maximum Gradient in feet per mile.	Maximum Curvature degrees per 100 ft.	Total Curvature	Average Gradient.	Elevation Outer Rail per degree.	Compensation for Curvature in ft. per degree.	REMARKS.
								Inches.		
La Junta to Trinidad.....	81.5	.....	.....	−30. +60.	5°	.....	.....	0.5	0.05	It is difficult to estimate the rise and fall of an engine with train, owing to the difference in length of train on the different stems.
Trinidad to Morley.....	10.1	800.	1.5	105.6	10°	865.1°	80.	0.5	0.05	
Morley to State Line.....	5.4	818.	.....	184.8	10°	945.°	151.4	0.5	0.05	
State Line to Willow Springs..	7.67	43.	990.	+184.8 −175.3	10°	1047.°	132.	0.5	0.05	
Willow Springs to Las Vegas..	110.25	.....	.....	70.	6°	.....	.....	0.5	0.05	
Switch Back.....	2.75	280.5	280.9	316.8	16°	1081.°13'	221.8 189.0	0.25	.....	

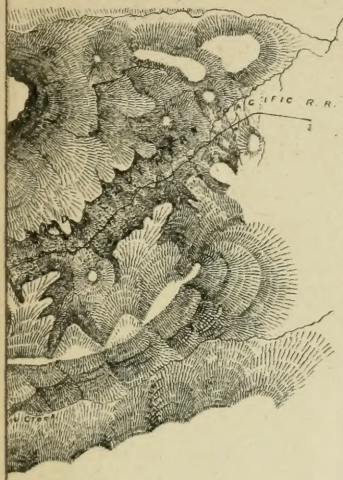
Plate L will show that there are but three short planes of descending gradients, of any considerable moment, between La Junta and Trinidad, going south, and as it was expected that there would be a large traffic in coal from Trinidad to supply the territory for 300 miles to the northeast, it was desirable to make the ascending grades, going north, as light as possible, consistent with economy in construction. In order to locate a line on 30 feet ascending grades to the north, from La Junta to Trinidad, —compared with the location of the Kansas Pacific Surveys made in 1871–72 on 70 feet maximum gradients *each* way,—a loss of 3 000 feet in distance was sustained.

From Trinidad the line follows the Valley of the Purgatoire—Picket-wire, in frontier language—two miles to the mouth of Raton Creek. Thence, turning sharply to the south, with both maximum curvature and maximum gradients, it ascends the northern slope of the mountain proper by Raton Cañon, on two planes.

The first plane from the mouth of Raton Creek to Morley, eight miles, is nearly a uniform ascent of 105.6 feet per mile. At Morley, with an elevation of 6 727 feet above tide-water, a water-tank, turn-table and side tracks have been established. The yard is on a gradient of 1.66 feet per 100, or 87.65 feet per mile. At the south end of this yard the second incline plane commences, having 3.5 per cent. maximum grades. Between Morley and the summit there are three miles of maximum, supported grade. The average ascent is 151.4 feet per mile.

The summit is passed by a tunnel which, when completed, will be 2 011 feet long, located on 1.9 per cent. ascending gradient, going south. The south portal is 7 584 feet above the sea, and the top of the mountain proper has an elevation of 7 767 feet. Thus, in 306 stations of 100 feet each, there is an ascent of 861 feet, or a uniform ascending gradient of 2.8 feet per hundred. At the south portal of the tunnel the line commences to descend the southern slope of the mountain, on 3.32 per cent. maximum gradients, to Willow Springs, which has an elevation of 6 595 feet above tide, having made a descent of 990 feet in 38 400 feet, or a uniform gradient of 2.58 per cent.

On the mountain division, from Trinidad to Willow Springs, maximum curves of 573.7 feet radius are freely used. Maximum grades are compensated for curvature at a rate of .05 feet per degree of curvature, each 100 feet. The outer rail has been elevated at the rate of ½ inch per degree of curvature.



MAP

AND

PROFILE

of the

D AND ARKANSAS VALLEY,

and the

MEXICO & SOUTHERN PACIFIC

RAIL ROADS

from

TRINIDAD, COL.

TO

WILLOW SPRINGS, N.M.

A. A. Atchison
Chief Engr.

J. D. Hurr
Asst. Engr.

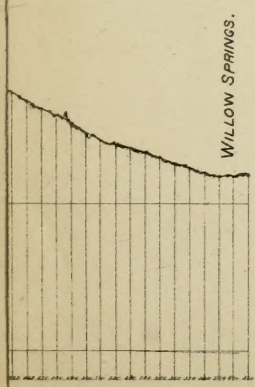
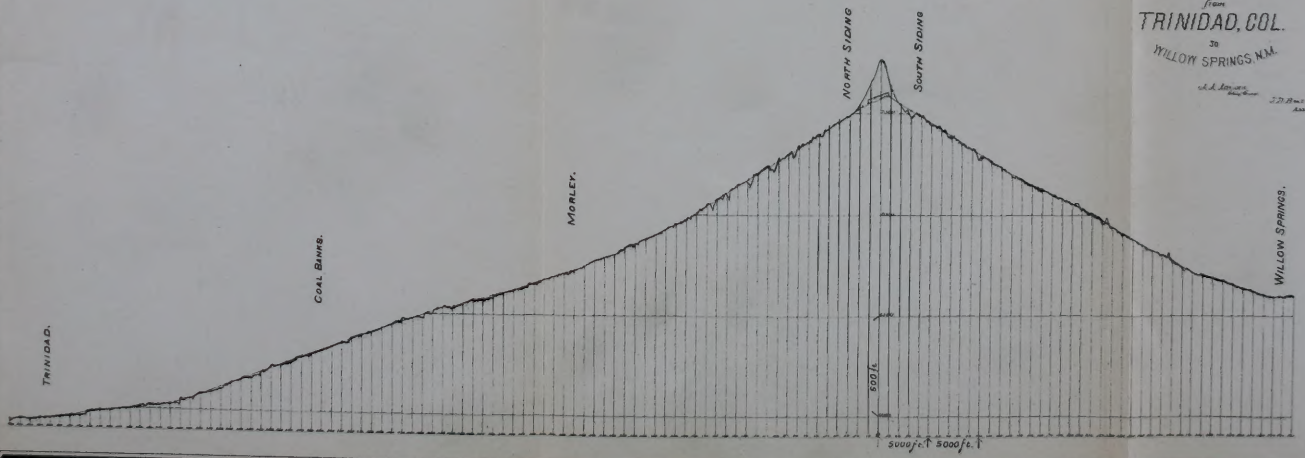


PLATE LI
TRANS. AM. SOC. CIV. ENG'RS
VOL. VIII. No. CLXXVII
BURR ON RAILROAD OVER
RATON MTS

MAP
and
PROFILE
of the
PUEBLO AND ARKANSAS VALLEY,
and the
NEW MEXICO & SOUTHERN PACIFIC
RAIL ROADS
from
TRINIDAD, COL.
to
WILLOW SPRINGS, N.M.



From Willow Springs to Las Vegas, "The Meadows," 110 miles beyond, the line has been located on 70 feet maximum gradients with 6° curves from maximum curvature, on which the work of construction has so far advanced that Las Vegas will be reached early in July.

The surveys from La Junta to Willow Springs were begun on the northern slope of the mountains early in March, 1878, by A. A. Robinson, Chief Engineer, with George B. Lake (now Sup. Western Division) First Assistant Engineer, who made the location on the north side, while the location on the south side was made by R. L. Engle, Division Engineer in charge of tunnel. A company force was at once organized, and grading commenced.

The excavation at each end of the tunnel being very deep, 56 feet at the north portal, and 50 feet at the south end, mostly in solid rock, a shaft near the south portal was begun on June 1st. The shaft reached the roof of the tunnel section, July 9th.

On August 21st, the north approach had progressed so far that the heading was commenced at that end, but up to August 31st, only 73 feet of heading and 19 feet of full section had been driven, 14 feet of the latter being that allowed for the section of the shaft.

At this time the track had reached a point 65 miles south of La Junta, and it became evident that the completion of the tunnel must be hastened or a temporary track built over the mountains, otherwise track would be detained at the tunnel several months. It was, therefore, decided at the first meeting of any Board of Railroad Directors held in New Mexico, August 31st, 1878, to build a temporary track over the mountain, to be used until the tunnel could be completed. A location for a "switchback" was made immediately, and the grading for it, begun on the 16th of September, was completed in the latter part of November.

The maximum grade on tangent on the mountain top line is 6 feet per hundred; curves of 359.3 feet, least radius. Gradients are compensated for curvatures, on the switchback, as follows:

On curves of 1 146 feet radius and over, 0.05 foot per degree of curvature.

On curves of less than 1 146 feet radius to curves of 573.7 feet radius, 0.075 foot per degree of curvature.

On curves with shorter radii than 573.7 feet, 0.086 foot per degree.

The descent of the south slope is on a maximum of 4.9 per cent. on

straight portions of the track, compensated for curvature at the same rate as on the north side.

It will be noticed by reference to Plate LII that the ends of each stem (of which there are six, counting the two constituting the ends of the main line), are approached by ascending grades. This practice has proved a very desirable precaution; for, during the progress of construction a portion of a train became unmanageable on account of the wheels sliding down the frosty rails, and would have gone beyond the stem, and down an embankment many feet high, but for the resistance of the adverse grade. On May 12th an engine did go over the embankment at the end of Stem No. 2, on account of the brakes on the train giving way—although the engine was provided with air brakes on drivers—and there would have been a very serious accident, but for the resistance of the adverse grade. Fortunately the damage was slight, and only to the engine.

Before the close of December, 1878, the track had been laid over the mountain, and the work of transporting material for the construction of 118 miles of the New Mexico & Southern Pacific Railroad began. Besides this material, since the road has been opened for traffic, a period of three months, merchandise freight to the value of from $150,000 to $175,000 has been transported to and from the town of Otero, 12 miles beyond the summit. The average tonnage transported over the Switchback daily, since it was completed, may be stated, including dead weight, as, Tonnage South, 420 tons per day; Tonnage North, 200 tons per day.

At first the Switchback was operated by the ordinary eight-wheeled American engines with 17″ × 24″ cylinders, 60″ driving wheels, weighing about thirty-five tons, from the Baldwin shops, and with a 16″ × 24″ engine, same class as the first from the Hinkley shops, with 64″ drivers. The working of these light engines may be summarized as follows:

La Junta to Trinidad,	60.	′	grades,	14	to	18	loads of	43,000	pounds.
Trinidad " Morley,	105.6′	"	"	8	"	11	" "	"	"
Morley " Tunnel,	184.8′	"	"	3	"	5	" "	"	"
" Switchback,"	316.8′	"	"	1	"	2	" "	"	"

The smaller number of cars being the number for the 16″×24″ cylinder engine; and the larger number of cars, the maximum capacity for the 17″×24″ cylinder engines.

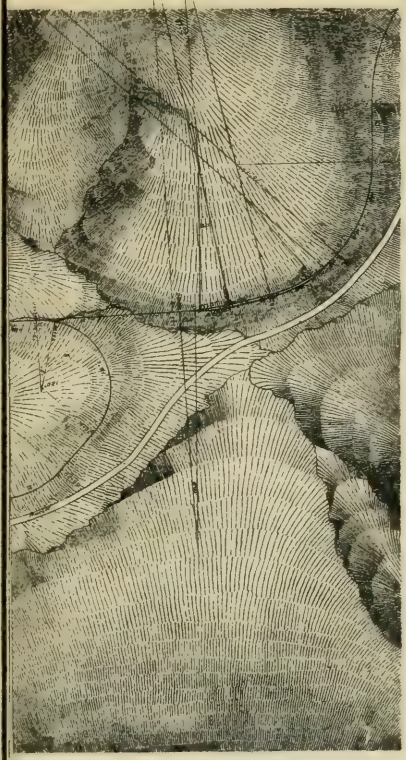
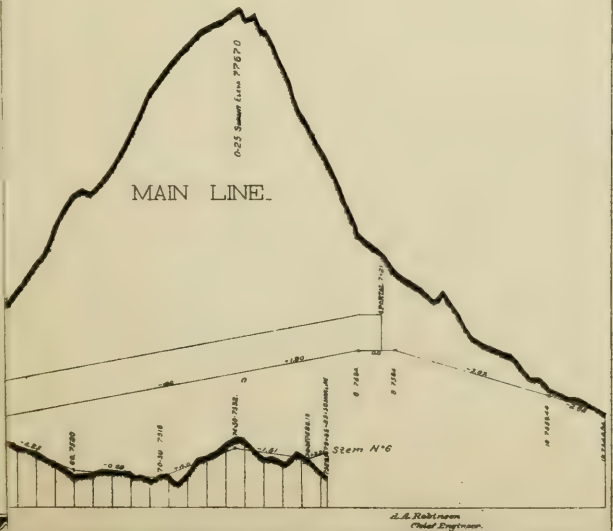


PLATE LII
TRANS.AM.SOC.CIV.ENG'RS.
VOL. VIII. No. CLXXXVII
BURR ON RAILROAD CURVES
RATON MT'S



Map & Profile
Main Line & Switchback
Raton Mountains,
N.M. & S.P.R.R.

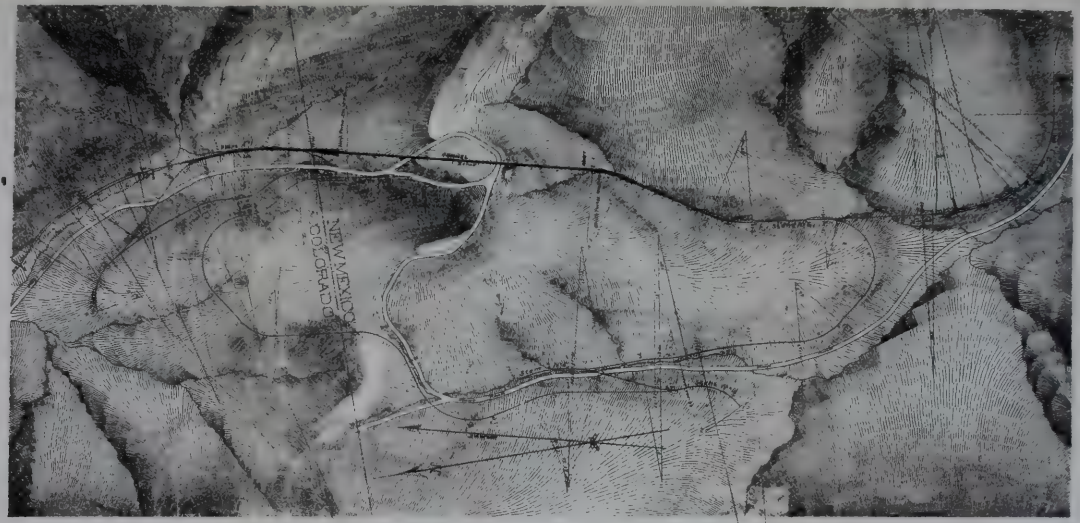
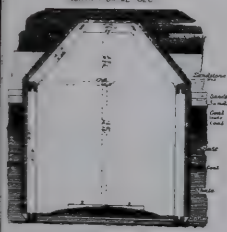


PLATE LII
TRANSACTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS
VOL. VIII. NO. CLXXX.
HURD ON RAILROAD CURVES
RATON MTS.

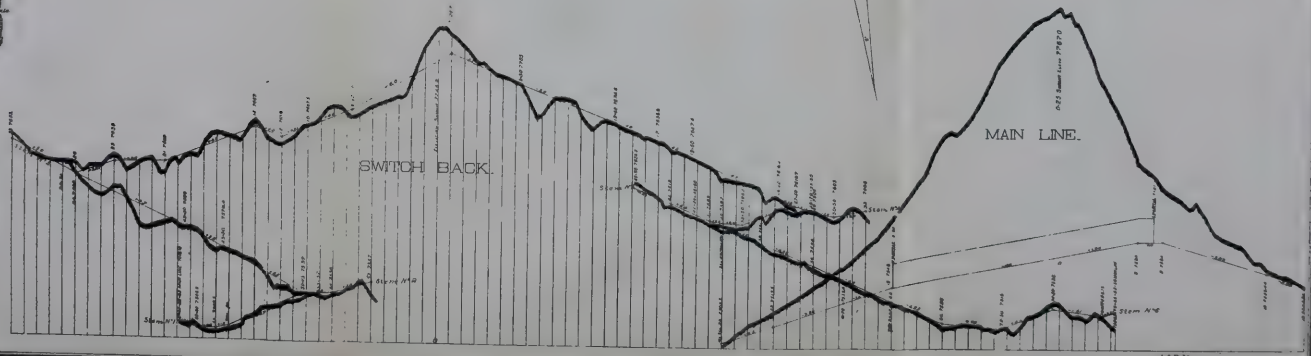
Horizontal Scale

Vertical Scale = ½ Horizontal

North Portal Sec.



South Portal Sec.



The best day's performance of any of these light engines on the mountain division was that of Locomotive No. 106, from the Hinkley shops, with 16″ × 24″ cylinders, 64″ drivers. This engine left Trinidad, empty, at 7 A. M., for the Summit, 15 miles distant, and, during the day, took twenty-five loaded cars from the North to the South Siding, $2\frac{3}{4}$ miles, and brought back as many empty cars, and arrived again at Trinidad at 7 P. M. This was accomplished by taking one load from North Siding and leaving it at the summit; thence returning to North Siding for a second loaded car, and again, for its third load; then, from the summit, taking the three loaded cars to the South Siding. This performance was at the time considered remarkable.

The engine was provided with Westinghouse Air Brakes on driving and tank wheels, as are all engines which work on this mountain line. Engines which were fitted with the Automatic Brake have had the arrangement changed into the common Westinghouse Air Brake; it having been found that this last gives the best results in regulating the amount of force applied to the air brakes, and the air gauge of the air brake always indicating the pressure in the reservoir before the brakes are applied, as well as during the operation. On the other hand, with the automatic device it is impossible to tell the pressure until, and, during the application of the brakes, unless the pressure is kept up to the blowing off point. A very essential thing to know, in working the Mountain Top line, is that the brakes and brake power are in good condition and under perfect control.

The performance of two coupled engines on the Mountain Division has not been double that of engine 106, whose remarkable day's work was made at great risk; but, from 7 A. M. to 7 P. M., 34 loaded cars have been taken over from the North to the South Siding, besides 10 loaded cars hauled from Trinidad to the Tunnel, the engines returning to Trinidad within the time mentioned.

The advent of the "Uncle Dick," a "Consolidation" eight-wheeled-connected engine from the Baldwin shops, revolutionized transportation on the "Mountain Top" line.

The principal dimensions of this locomotive are:

Cylinders	20″×26″	Number of Tubes	213
Driving wheels	42″	Diameter "	2″
Total wheel base	22′—10″	Length "	10′—11⅜″
Rigid "	9 feet.	Heating surface, fire box,	153□′
Diameter boiler, inside	57″	" " flues	1223.84□′
Length fire box	119″	Total heating surface	1376.84□′
Width "	33⅜″		

Capacity of tank on boiler ..... 1,200 gallons.
Estimated weight, including weight of saddle tank in working order ..... 115,000 pounds.
Estimated weight on drivers ..... 100,000 "

In this connection, it may be proper to say that "Uncle Dick" Wootten, the old pioneer after whom the locomotive is named, settled in the Raton Cañon in 1847 ; that he was with Fremont, Kearney, and Kit Carson ; and that he saw Fisher when he made his observations from the peak that bears his name.

The performance of this engine on the mountain division is as follows :

On the 2 per cent. incline, Trinidad to Morley—482½ tons hauled 8 miles per hour.

On the 3.5 per cent incline, Morley to Tunnel—258½ tons hauled 8 miles per hour.

On the "Switchback"—194 tons hauled 6 miles per hour, including time lost in opening and closing six switches. The foregoing weights do not include the weight of the engine.

On the 2 per cent. gradients the resistance is :

Gravity	$\frac{2\times2000}{100}$	=	40 pounds per ton.
Wheel friction		=	6 " "
Wind pressure	(say)	=	1.8 " "
Total resistance			47.8 " "

Traction = 482.5 + weight of engine say 60 tons = 542.5 tons.

Then, traction = 542.5 × 47.8 = 25,931 pounds.

Weight of engine on drivers = 100,000 pounds.

$$\text{Adhesion} = \frac{25{,}931}{100{,}000} = \frac{1}{3.86},$$

or somewhat greater than ¼ the insistent weight.

TABLE 2.

PROGRESS OF HEADINGS AND ENLARGEMENTS OF RATON TUNNEL, N. M. & S. P. R. R.

1878. MONTHS.	SHAFT 8 FT. BY 14 FT.				HEADING NORTH.				ENLARGEMENT NORTH.				HEADING SOUTH FROM SHAFT.				HEADING NORTH FROM SHAFT.				ENLARGE'T SOUTH SIDE				REMARKS.
	Feet	Cubic Yards.	Labor Days.	Powder, lbs.	Feet	Cubic Yards	Labor Days.	Powder, lbs.	Feet.	Cubic Yards.	Labor Days.	Powder, lbs.	Feet.	Cubic Yards.	Labor Days.	Powder, lbs.	Feet.	Cubic Yards.	Labor Days	Powder, lbs.	Feet.	Cubic Yards	Labor Days.	Powder, lbs.	
June	31.0	128.6	318	720																					
July	21.0	87.1	493	1 230																					
August	11.8	48.9	327	1 613	18.0	72.0	160	288					25.0	75.0	260	337	16.0	48.0	180	240	5.0	31.9	30	104	1/3 month in shaft. 1/4 " " heading.
September					64.0	256.0	350	1 024	53.0	433.5	600	1 192	89.0	267.0	450	1 200	34.0	102.0	200	510					
October					59.0	236.0	338	944	62.0	507.2	606	1 335					60.0	180.0	416	900					
November					85.0	340.0	382	1 360	75.0	613.5	499	1 687					72.0	216.0	421	1 080	19.0	121.0	114	393	1/5 month in South Enlargement.
December					78.0	312.0	325	1 248	81.0	662.6	500	1 822					76.0	228.0	427	1 140	58.0	369.5	205	1 201	
Total progress	63 8	264.6	1 138	3 563	04.0	1216.0	1 545	4 864	271.0	2216.8	2,205	6 096	114.0	342.0	710	1 537	258.0	774 0	1644	3 870	82.0	522.4	349	1 698	
Best month	31.0	128.6	493	1 613	85.0	340.0	382	1 360	81.0	662.6	500	1 822	100.0	300.0	1 040	1 348	76.0	228.0	427	1 140	58 0	369.5	205	1 201	
Average	23.2	96.2	413	1 296	71.5	286.0	3 635	1 144	67.75	554.2	551.2	1 524	91.2	273.6	568	1 230	60.7	182.1	386.8	910	46.8	298.1	199.4	970	
1879.																									
January					103.0	412.0	416	1 648	84.0	687.1	600	1 890					84.0	252.0	442	1 260	92.0	586 0	653	1 904	
February					85.0	340.0	384	1 360	78.0	638.0	528	1 755					78.0	234.0	408	1 170	85.0	541.5	590	1 760	
March					97.0	388.0	410	1 552	104.0	850.7	654	2 340					94.0	282.0	460	1 410	96.0	611.5	665	1 988	From March 1, Hercules No. 2 principally used, but shown here as black powder, as 2½ is to 1.
April					90.0	360.0	400	1 440	100.0	818.0	650	2 250					116.0	348.0	552	1 740	145.0	923.6	899	3 002	
May					136.0	544.0	540	2 176	95.0	777.1	648	2 137					111.0	333.0	550	1 665	155.0	987.3	1000	3 208	
Total progress					511.0	2044.0	2 150	8 176	461.0	3770.9	3 080	10 372					483 0	1449.0	2412	7 245	573 0	3649.9	4807	11 862	
Best month					136.0	544.0	540	2 176	104.0	850.7	654	2 340					116.0	348.0	552	1 740	155 0	987.3	1000	3 208	
Average					102.2	408.8	430	1 635	92.2	754.2	616	2 075					96.6	289.8	482.2	1 449	114.6	930.0	761.4	2 372	

On the 6 per cent. gradient:

Gravity.....	$\frac{6 \times 2{,}000}{100}$	= 120	pounds per ton.
Wheel friction	=	6	" "
Wind pressure	=	1.8	" "
Total resistance....		127.8	" "

Traction $= 254 \times 127.8 = 32{,}461$ pounds.

$$\text{Adhesion} = \frac{32{,}461}{100{,}000} = \frac{1}{3.08},$$

or, slightly less than $\frac{1}{3}$ the insistent weight.

The difference between the traction on the 2 per cent. and on the 6 per cent. gradients is explained by the fact that the locomotive has not been tested to her full capacity on the 2 per cent. gradients. The loads mentioned above were started from a perfect stand-still, and without taking the slack of the train, and without slipping drivers.

The best day's work on the Mountain Top Line with the locomotive Uncle Dick has been as follows: Left Trinidad for Morley at 7 A. M., with 15 loaded cars, besides tanks of coal and water; drew 10 loaded cars from Morley to Tunnel, and during the day took 46 loaded cars from the North to the South Siding, and brought back as many empties; reached Trinidad at 7 P. M. Time, 12 hours, of which $2\frac{1}{2}$ hours were lost in waiting for trains and for meals.

The ordinary round trip, $5\frac{1}{2}$ miles, requires 50 minutes time. The ordinary train consists of 7 loaded cars of 43,000 pounds each, tank of coal 44,000 pounds, and engine say 120,000 pounds. Eight loaded cars can be taken over at one time quite readily; and, at one time, nine loaded cars were taken at one trip, so that, during the day of ten hours, 6,020,000 pounds could, very readily, be moved over the mountain with one engine. It will be noticed that the capacity of engines of this class is more than double that of two American engines of $16'' \times 24''$ cylinders; while the quantity of coal consumed is but little more than that consumed by a single light engine.

As to the matter of controlling trains on these steep inclines it is a question of brake power and adhesion to the rail. In frosty weather, backing down an incline, the ordinary eight-wheeled engine, not having a sand pipe in the rear of its drivers, will lose its "bite" or adhesion to the rails, and slide down hill quite as readily as if placed on runners on

good sleighing. In such cases brakes are of small account. All engines should be provided with sand pipes placed so as to deliver sand on the rail, when going in either direction.

Under fair conditions of rail, one single hand-brake, in good order, to each car, together with the driver and tank brake, with three brakemen to a train of eight cars, is sufficient for safety, unless the train should acquire a speed of 18 to 20 miles per hour, in which event all the wheels in the train might be skidded far enough to lead to disaster.

With the Uncle Dick this danger is reduced to a minimum, for, as sand can be delivered along the rail in front of all the wheels, and two sets of air brakes may act on all drivers simultaneously with sufficient force to slide all the wheels, the maximum of adhesion is obtained.

The Uncle Dick is provided with water pipes for delivering a small jet of water on the flanges of each flanged driving wheel. In backing over the sharp curves of the "Mountain Top" line this jet of water is very beneficial in preserving the flanges of the drivers and also the head of the rails.

The "Switchback" is laid with 56 pounds iron rails, common splices, pine ties on straight line, oak ties at the joints of rails, and on all curves having less than 1,146 feet radii. A cast iron bracket fits up against the outer side of each rail on curves with 716 feet, and less, radii, while a guard rail of iron is placed on the inner side of the inside rail. These precautions hold the track in gauge.

The gauge of rails is 4′—8¼″ on straight portions of the track to 4′—9¾″ on the 16 degree curves.

The outer rail on curves was elevated ¼″ per degree of curvature per hundred feet. The track was operated with this elevation, for some time, when, it being noticed that the inner rail was becoming much kinked, an elevation of ⅛″ per degree was given. This proved to be an error, as, with this elevation, the Uncle Dick seemed inclined to leave the rail in the direction of a tangent to a curve, even at slow rates of speed; therefore, the original elevation of ¼″ per degree, on curves, was restored. This has given the best results.

During the first two weeks' work of the Uncle Dick its performance was anything but satisfactory owing to the frequency with which it left the rails at frogs and switches. This was caused, at the frogs by insufficient width of gauge and the inability to elevate the outer rail; at the switches partly by the insufficient weight of rails, partly by the

PLATE LIII
TRANS. AM SOC. CIV. ENG'RS.
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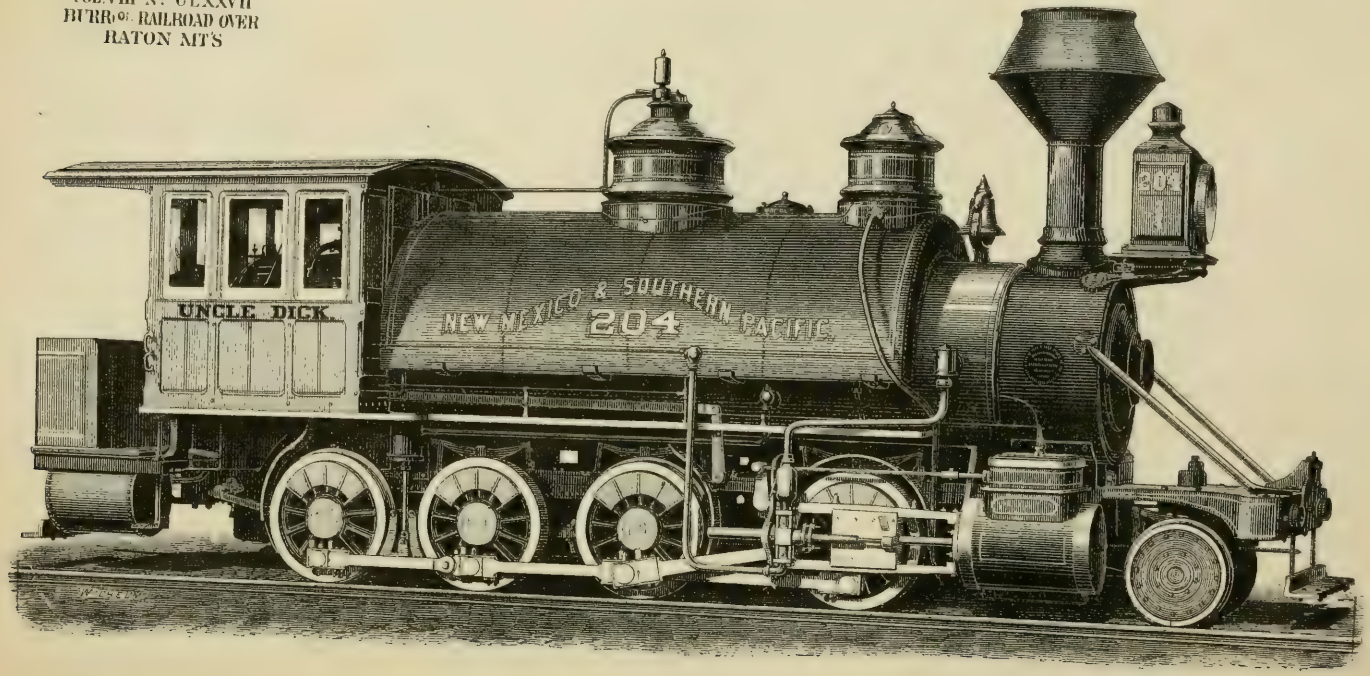
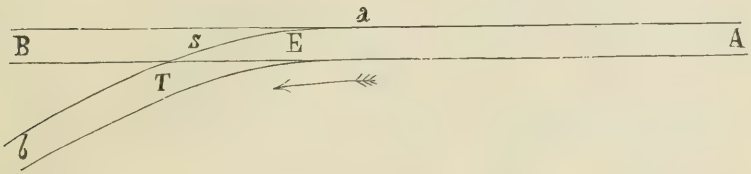
BURROUGH. RAILROAD OVER
RATON MT'S



small amount of play to the switch-rod connections, and very much by the great length and leverage between the trailing axle and the centre of the truck wheels under the tank.

From the plate of the locomotive Uncle Dick it will be seen that the original intention was to operate it as a tank engine. It was found, upon trial, that this could not be done with economy, therefore the ordinary tank was attached, and air brakes supplied in the usual manner.



If we suppose the figure to represent a portion of track near a switch with a descending grade from *A* to *B*, with the tank at *T*, engine at *E*, and the loaded train from *A* to *a*, moving in the direction of the arrow, and let the air brakes be suddenly applied to the tank wheels, the resultant of the two forces would throw the trailing wheel over against the slide rail *S* with sufficient force to cause a "lip" on the lead rail, and the engine would climb the lead rail and go over on to the main track.

This was obviated, in a measure, by taking off the coal bunker, reducing the length between engine and tank, and putting an additional set of air brakes on the drivers. At first there was but one pair of air brakes on the engine—those between the rear and next pair of drivers. These were used as little as possible, tank brakes being used instead, in order to preserve, as nearly as possible, the same diameter for all the wheels until the second pair of brakes could be supplied.

Since the foregoing defects have been remedied as much as possible, there has been no difficulty in working the Mountain Top Line, with the heavy engine. Indeed, it is believed that the Consolidation engine travels the 16 degree curves with as much ease as an ordinary American engine, and causes less wear of track and permanent way.

DISCUSSION

On the Paper "The Construction of the Atchison, Topeka and Santa Fé Railroad over the Raton Mountains," at the meeting of the Society, October 1st, 1879,

By J. Foster Flagg and Edward P. North.

J. Foster Flagg.—I have been looking forward with considerable interest to the appearance of the paper by Mr. Burr, but must confess to some disappointment in not finding therein more details of location and construction. I may, however, have overrated the difficulties of the former, which does not need, therefore, any especial description. The work of locating the developments of the track and the switch-backs of the Oroya Railroad, on the precipitous sides of the Rimac Valley in Peru, was one of exceeding difficulty,—which, by the by, I was in hopes we should have had a full description of long since from Mr. V. G. Bogue, Member of the Society, the engineer in charge of a division in the most difficult part of the route, he having intimated to me an intention of preparing a paper to this end several years ago,—and I may have been erroneously led to suppose there were similar difficulties here.

The details of grade and curvature are, however, quite valuable in connection with the performances of the consolidation engine, as a guide in estimating the possible capacity of roads in mountainous localities, where excessive grades and curvature have to be resorted to, whether as a temporary expedient or for permanent location. If the actual expenditure of fuel, etc., were given, we could also estimate closely the cost of transportation per ton mile.

On the Iquique and La Noria Railroad, in Southern Peru, and doubtless in other localities, the same expedient of laying the stem of the switch-back on a sharp up grade is resorted to, and its importance is very great in preventing or diminishing the number of accidents from runaway trains. This road has maximum grades of 4 per cent. only, but the great length of continuous steep descent makes the control of trains fully as difficult, probably, in the winter season, as upon the line over the Raton Mountain. From the station of Santa Rosa to the sea at Iquique, a distance of 17.2 miles, the track falls nearly 2 900 feet, an average of about $3\frac{1}{10}$ per cent. for the entire distance. Proceeding downwards from Santa Rosa, at the end of 7.7 miles, at Molle, the track,

being then about 1 600 feet above the sea, strikes the face of a steep cliff falling nearly to the ocean beach, and follows the face of the cliff for 7.5 miles to the only reversing station,—the remaining two miles having slight grades. There is thus a constantly descending grade for 15.2 miles, the average being at least $3\frac{4}{10}$ per cent. for this distance, with a maximum of 4 per cent., and very little less than 3 per cent. Although there is neither rain nor frost in this locality, there is in winter a very damp fog, which seems to impart a peculiar greasiness to the rails, making it very difficult to hold the trains, especially if they have once acquired any speed : and a train having fairly entered upon the *cuesta*, or face of the cliff, with a high velocity, the long distance to the reversing station, with numerous curves of 12° to 16° curvature on the way, renders its destruction almost certain.

After several severe accidents had happened on the *cuesta*, a switch was built at its head, on the pampa at Molle, to catch any runaway trains from above. This, like the switch-back, was built with a heavy ascending grade, with a self-acting split-rail switch, set to throw all descending trains upon the turn-out, and requiring the switch-tender, after throwing over the points *to hold them there* during the passage of a train in order that it might continue on its course down the main line. Notwithstanding this safeguard, a short time subsequent to its construction, by some stupid misunderstanding of signals, or lack of proper system in signaling, a train, of which the driver had lost control, came thundering by whilst the switch tender held open the path leading to its destruction. The result was an accident, which, with their insufficient appliances, blocked the road for five days, and a loss of life that would be appalling if its numbers could be stated ; but the native railroad authorities managed to get the dead bodies of the poor friendless *peones* disposed of in some way, so that the amount of slaughter was never known.

At Sta. Rosa Station is a piece of level track, nearly half a mile in length, and above and beyond is the most difficult stretch of track on the road. Here, within a distance of 0.7 miles, are eight consecutive reverse curves, with no perceptible tangents between, with radii of only 330 to 570 feet—mostly under 400 feet—and with a total curvature of 535 degrees; it is all on a heavy ascending grade, a portion in the midst of the curves being 4 per cent.

In 1872 to 1874, when I was acquainted with the road, the locomotives were mainly Fairleigh's double enders, and it is interesting to compare

the performance of these much vaunted engines with that of "Uncle Dick."

The Hercules, one of the heaviest and best of Fairleigh's on the Iquique Railroad at that time, had the following dimensions:

Cylinders, 4 in number.....15″ × 22″	Heating surface, fire box.....138□′
Driving wheels, 12 do.....42″	" " tubes .....1 543□′
Internal diam. of boilers .....45″	Total heating surface.....1 681□′
Length of each barrel.....9′ 9″	Steam pressure in boilers .... 130 lbs.
Length of fire box.....7′ 6″	Total weight empty.....44 tons.
Width " .....3′	" " with boiler filled.48 "
Height " .....4′ 9″	Water carried in tanks (2 200 imp. gallons).....10 "
Number of tubes 286	Fuel in bunkers..... 2 "
Int. diameter of tubes .....1¾″	Total weight of loaded engine..60 "
Length of tubes .....11′ 1″	
Area of fire-grate.....23□′	

Speaking from remembrance only, the above steam pressure was frequently much exceeded, to enable the engine to pull over difficult places.

As the engine first drew her supply of feed water from tank cars in the train, which were left on the way at sidings as emptied, its actual weight over the worst portion of the road must have been nearly her full loaded weight—certainly as much as 58 tons; and, like most of Fairleigh's engines, the entire weight was upon the 12 drivers. (The above weights and dimensions being from English sources, the tons are, doubtless, gross ones.)

The most difficult portion of the road below Sta. Rosa, where the engines were frequently stalled, and compelled to stop for some time to get up steam, is a 4 per cent. grade upon a reverse curve, the sharper curve being, I think, about 16° (not sharper than that), and more than long enough to receive an upward bound loaded train.

Assuming, with the author, an equalization of 1° in curvature with 0.05 foot grade per 100 feet—which, being equal to 1 lb. per net ton traction per degree of curvature, is a sufficiently liberal allowance, to say the least, on these sharp curves, in view of the experiments upon the Metropolitan Railroad referred to by Mr. Chanute (Trans. Am. Soc. of Civ. Eng., Vol. VII, p. 98,)—the work of the engine would be only that of hauling its train up $4\frac{8}{10}$ per cent. grade on a tangent.

Immediately above Sta. Rosa, the reverse curves above described, probably render the ascent more difficult from their length so reducing

steam pressure in the boilers, as to make it exceedingly difficult for a heavily loaded engine to pull through, even with the benefit of the speed obtained by a run upon the level track at the station, although the grade is no steeper nor the curves much sharper than at the most difficult point below Santa Rosa. It is probably equivalent to a $4\frac{9}{10}$ per cent. grade on a tangent.

As stated by the English superintendent of motive power and machinery at that time, the Hercules had taken up 150 tons (gross), but he considered this amount too much for the engine, and that 120 tons (gross) was a fair working load.

My own opinion, from frequent journeys over the road—although from the very promiscuous loading of the flats, it was difficult to judge of the amount of freight on each car—is that the latter estimate is quite a liberal one. I give as a sample the minutes of one trip, premising that all the cars were open flats, that the English ones were of ordinary English make on 4 wheels only, that the iron tank cars, also on 4 wheels, carried each about $10\frac{1}{2}$ net tons of water, that "Engineers' Camp" siding is a short distance above the Santa Rosa curves, and that from thence to the terminus at La Noria, the grades are moderate.

"Hercules left Iquique a little before 10 A.M., with three tank cars only; took on 3 loaded American and 1 loaded English car at the reversing station. Arrived at Molle ($9\frac{1}{2}$ miles) at 11 A.M.; took one more loaded American car, and left one tank after emptying it; two hours spent at Molle in transferring water, and *getting up steam*. Reached Engineers Camp (19 miles from Iquique) at 3 P.M.; 3 loaded English, 7 empty English, and 3 empty American cars added to the train, and one more tank left behind. Train arrived at La Noria ($33\frac{1}{3}$ miles from Iquique) at 6 P.M. Water being nearly exhausted (8 500 gallons taken up exclusive of boiler charge) engine returned without load."

Other engines of the same make were ordered, during the time spoken of, with 17 × 22 inch cylinders, 45 inch drivers, and 2 059 square feet heating surface, but I have obtained no record of their performance.

Edward P. North.—In the fall of 1868 I was directed to locate a line for a temporary track, eight miles long, around some heavy work at the head of Echo Canon, Union Pacific Railroad.

It was found advantageous to employ a grade of $145\frac{1}{2}$ feet per mile and two Y's in getting down into the valley of the creek that was followed. The stems of the Y's, which were long enough to hold seven

freight cars and a locomotive, had a grade of 145½ feet per mile against any train that came on them, and were extended in sharp vertical curves. At the foot of the heavy gradient, grading was done for a safety spring switch like the one described by Mr. Flagg, but track was never laid on it, as no difficulty was found in controlling the small trains that the Y's would hold. As far as known by the writer, this was the first instance in which such vertical curves were used.